ISSN 0040-6015, Thermal Engineering, 2013, Vol. 60, No. 9, pp. 653–659. © Pleiades Publishing, Inc., 2013.
Original Russian Text © B.F. Balunov, V.A. Balashov, V.A. Il'in, V.V. Krayushnikov, V.D. Lychakov, V.V. Meshalkin, A.N. Ustinov, A.A. Shcheglov, 2013, published in Teploenergetika.

NUCLEAR POWER STATIONS

Thermal–Hydraulic Tests of a Recirculation Cooling Installation for the Rostov Nuclear Power Station

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Abstract—Results obtained from thermal–hydraulic tests of the recirculation cooling installation used as part of the air cooling system under the containments of the Rostov nuclear power station Units 3 and 4 are presented. The operating modes of the installation during normal operation (air cooling on the surface of finned tubes), under the conditions of anticipated operational occurrences (air cooling and steam condensation from a steam–air mixture), and during an accident (condensation of pure steam) are considered. Agreement is obtained between the results of tests and calculations carried out according to the recommendations given in the relevant regulatory documents. A procedure of carrying out thermal calculation for the case of steam condensation from a steam–air mixture on the surface of fins is proposed. The possibility of efficient use of the recirculation cooling installation in the system for reducing emergency pressure under the containment of a nuclear power station is demonstrated.

Keywords: thermal–hydraulic tests, heat transfer, finned tubes, heat exchanger, condensation, steam–air mixture, air cooler

DOI: 10.1134/S0040601513090012

The system for cooling air under the containments of Units 3 and 4 at the Rostov nuclear power station (NPS) contains a number of recirculation cooling installations (RCIs) having similar designs but with different heat removal capacities. The RCIs supplied to the Rostov NPS were designed by the Energomash-Kapital Company's design office and manufactured by the Ventilation Product Works owned by the same company (the city of Volgodonsk).

DESCRIPTION OF THE INSTALLATION, TEST RIG, AND MEASUREMENT PROCEDURE

The tested Type ROU-6.3 installation comprised a heat exchanger connected via an air duct to a VR-300-45-4 fan driven by a 4-kW AIR100L4 electric motor, all erected on a common frame (Fig. 1). In simulating the conditions of anticipated operational occurrences and accident conditions, an additional 0.7-m-long compartment was installed at the inlet orifice of the RCI air socket with a cross section of 1.2 × 0.45 m (Fig. 2). The additional compartment had the same cross section as that of the socket. A steam distribution manifold with a size of 51 × 2.5 mm (diameter × thickness) was placed at a distance of 100 mm from the external orifice of this compartment along its horizontal axis. The manifold had two rows of holes 3.2 mm in diameter, by 21 holes in each row arranged in a staggered manner with respect to another row, and with a pitch of 55 mm between the holes. The holes were oriented at an angle of 60° to a horizontal plane and directed toward the heat exchanger; i.e., the rows of holes were shifted with respect to each other by 120°. The 0.9-m-long segment from the steam inlet to the first row of heat exchanger tubes served for mixing the flow. In simulating the mode of anticipated operational occurrences, the fan continued to operate, and the external orifice of the additional compartment was held open (Fig. 3). In simulating accident conditions, the fan was stopped, and the external orifice of the additional compartment was closed by a plug. Steam flowrate was adjusted so as to displace air from the heat exchanger, due to which a temperature of around 100°C was maintained in the fan outlet socket.

The water-cooled heat exchanger contained 76 finned tubes produced by EK Energetik (the city of Asbest) made of Grade 08Kh18N10T steel. Continuous contact between the tubes and inner edges of spirally wound finning was obtained by high-frequency welding. The tubes had a size of 25 × 3 mm, and the fins had a diameter of 44 mm. The fins had the thickness $\delta_f = 1$ mm and pitch $S_f = 4.5$ mm. The finning factor, defined as the ratio of the tube and fins total external surface area to the bearing tube surface area, was $\varphi = 7.0$. The tubes were arranged with respect to one another at the vertices of an equilateral triangle with a